Management of Chronic Ruptures of the Achilles Tendon
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CURRENT CONCEPTS REVIEW
Management of Chronic Ruptures of the Achilles Tendon
By Nicola Maffulli, MD, MS, PhD, FRCS(Orth), and Adam Ajis, MRCSEd

Chronic ruptures of Achilles tendons are those that present four to six weeks after the original injury. They have become more common as acute Achilles tendon injuries have become more frequent, and they are associated with considerable functional morbidity.

Most surgeons agree that chronic ruptures should be managed operatively.

Diagnosis is based predominantly on history and clinical examination. Real-time, high-resolution ultrasound and magnetic resonance imaging are helpful in preoperative planning or as a diagnostic aid.

Local tissue, local tendons, and allografts can be used to reconstruct the tendon, and end-to-end repair is possible if the gap is <2.5 cm.

Compared with acute injuries, chronic injuries are associated with a higher rate of postoperative infection and more prolonged recovery.

Ruptures of the Achilles tendon are especially common in middle-aged men who occasionally participate in sports. In some cases, a patient sustains a rupture, but this is not diagnosed and the patient presents with a chronic rupture four to six weeks later. Although there is still much controversy about how to manage acute ruptures, most surgeons agree that chronic ruptures should be treated operatively when possible, as they are associated with considerable functional morbidity. An ankle-foot orthosis can be used to manage a chronic rupture in a low-demand individual or in a patient in whom operative management is contraindicated.

Pathophysiology
A chronic rupture of the Achilles tendon causes difficulty with and impairment of ankle plantar flexion. The tendon sheath often becomes thickened and adherent to the retracted ends of the tendon, and there is minimal repair tissue in the gap.

The proximal stump is often conical and adherent to the fascia posterior to the flexor hallucis longus muscle belly.

The distal stump often looks bulbous. If the plantaris tendon is present, it may be hypertrophied.

Thickened scar tissue commonly bridges the rupture site in an attempt at repair. A well-organized connective tissue repair response was seen fifty-six days after resection of calcaneal tendons in rabbits, but a fascicular arrangement of collagen fibers typical of a tendon was still not present by 240 days. The repair tissue is not as strong as intact tendon, and it elongates with time.

Retraction of the proximal stump results in shortening of the intact proximal gastrocnemius-soleus complex. This reduces its biomechanical efficiency and the contractile force that the muscle can develop. The overall effect is weakness of ankle plantar flexion and hence a flat-footed, nonpropulsive gait on the affected side.

Diagnosis
Chronic Achilles tendon ruptures normally present as a result of a misdiagnosed, neglected, or unrecognized acute rupture. Patients may describe a sudden sharp pain in the calf, as if...
kicked from behind\(^\text{1}\), while they were engaged in sports activity. Alternatively, they may recall a minor injury with an initial episode of heel pain. Subsequently, routine daily tasks such as walking uphill or climbing stairs become difficult\(^\text{3}\).

Diagnosing an acutely ruptured Achilles tendon is usually straightforward if the history and findings on examination are clear. Nevertheless, as much as a fifth of these lesions can be missed\(^\text{22}\). In one study, nine (36%) of twenty-five elderly patients had a delay of more than one week before treatment because the condition was not diagnosed at the time of injury\(^\text{23}\).

When a patient has a chronic rupture, the pain and swelling have often subsided and the gap between the tendon ends has filled in with fibrous tissue\(^\text{23-25}\) (Fig. 1). In addition, active plantar flexion, although weak, may be possible through the action of the tibialis posterior, flexor hallucis longus, flexor digitorum longus, and peroneal muscles. These residual functions may make it difficult to confirm the correct diagnosis through clinical examination alone\(^\text{26}\). A limp is often present\(^\text{27}\). A high index of suspicion is needed, and a range of special tests and investigations can aid in accurate diagnosis.

**Clinical Examination**

On inspection, there may be a visible gap at the rupture site. The calf muscles may be wasted. The long toe flexors may accommodate for the lack of function of the gastrocnemius-soleus complex, producing clawing of the toes and an apparently higher medial arch of the foot.

The clinical tests described here have been systematically studied for the diagnosis of acute ruptures; their applicability to chronic cases has, to our knowledge, not been investigated.

The calf squeeze test, also known as the Thompson test, was first described by Simmonds in 1957\(^\text{28}\). The patient lies prone on the examination table with both feet over the edge. The calf is squeezed and, if the Achilles tendon is intact, the foot will plantar flex as the tendon connects the gastrocnemius-soleus complex to the calcaneus. When the tendon is torn, and thus no longer connects the gastrocnemius-soleus complex to the calcaneus, the foot will not plantar flex as much as it does on the normal side.

The Matles test\(^\text{29}\) is also performed with the patient lying prone. The knees are flexed to 90°. The ankle on the ruptured side will assume a more dorsiflexed position as compared with the normal side. This is due to the absence of normal tension under which the tendon connects the gastrocnemius-soleus complex to the calcaneus and hence the effects of gravity make the foot dorsiflex more on the injured side.

With the O’Brien needle test\(^\text{30}\), also done with the patient prone, a hypodermic needle is inserted off the midline 10 cm proximal to the calcaneal insertion of the Achilles tendon, such that its tip lies within the substance of the tendon. The ankle is then manually plantar flexed and dorsiflexed by the examiner. If, on dorsiflexion, the pin moves so that it points proximally, the area of tendon between the pin and calcaneus is presumed to be intact; if not, then a rupture is probable.
Copeland described a test performed with a sphygmomanometer. A sphygmomanometer cuff is wrapped around the midpart of the calf with the patient lying prone. The cuff is inflated to 100 mm Hg (13.3 kPa) with the foot in plantar flexion. The foot is then dorsiflexed by the examiner. If the pressure rises to approximately 140 mm Hg (18.7 kPa), the musculotendinous unit is presumed to be intact. If the pressure on dorsiflexion remains approximately the same, a rupture is presumed.

If two of the tests described above are positive, a diagnosis of a ruptured Achilles tendon is certain.

**Imaging**

Lateral radiographs of the ankle can be used to aid in the diagnosis of a ruptured Achilles tendon. For example, Kager’s triangle, a small fat-filled space between the anterior aspect of the Achilles tendon, the posterior part of the tibia, and the superior aspect of the calcaneus, can become distorted. Also, deformation of the distal tendon contours due to loss of tone can be seen. Radiographs can further aid in diagnosis by ruling out other diagnoses such as calcaneal avulsions or other osseous injuries. Calcification in the distal stump of the Achilles tendon is sometimes seen in patients with a chronic rupture. In one study, three of seven patients had evidence of this on plain radiographs.

Real-time, high-resolution ultrasonography is inexpensive, rapid, and dynamic. However, it is highly user-dependent, requiring training and experience to correctly interpret the images. A linear-array transducer probe is held perpendicular to the skin overlying the tendon. Ultrasound gel is used to ensure that the optimal amount of energy is returned to the transducer probe, enabling good dynamic and panoramic images of the tendon. The longitudinal collagen fibers in the Achilles tendon reflect ultrasonic energy, and high-frequency probes show the tendon best. A normal tendon appears as a hypoechoic, ribbon-like image contained between two hyperechogenic bands. These bands are separated when the tendon is relaxed and are more compact when the tendon is under tension. When the Achilles tendon is ruptured, ultrasonography shows tendon discontinuity with decreased or increased echogenicity, depending on the chronicity of the rupture (Fig. 2).

*Fig. 2*  
A real-time, high-resolution longitudinal ultrasound scan of a seventeen-week-old chronic rupture of the Achilles tendon in a fifty-five-year-old man. Note the loss of the normal contour of the tendon, with hyperechogenicity, and a bulbous appearance of the distal stump (arrow).

Magnetic resonance imaging can show in detail the condition of the ends of completely ruptured tendons. A normal Achilles tendon is viewed as an area of low signal intensity on all sequences. It tapers smoothly with no focal defects. The dark band of the tendon itself can be distinguished from the high signal intensity of the pre-Achilles fat pad. Chronic ruptures are seen as an area of low signal intensity on T1-weighted images and as discontinuity and altered signal on T2-weighted scans. The condition is best appreciated on sagittal views (Fig. 3).

**Management**

Management of chronic Achilles tendon ruptures is challenging. The ends of the tendon are frequently retracted and have an atrophic appearance.
Conservative Management

Christensen reported on a series of fifty-one patients with fifty-seven ruptures, nearly two-thirds of which were chronic. Eighteen of these ruptures were treated conservatively, either because the operation was contraindicated or refused (seven ruptures) or because the rupture was several months old and the triceps surae showed clinical signs of regaining strength and hence the injury was managed without any further conservative or surgical intervention (eleven ruptures). The result was satisfactory (i.e., the gait was normal, the patient returned to his or her previous occupation, and there was slight or no discomfort) in ten of these eighteen nonoperatively treated cases. The improvement occurred slowly, sometimes over several years, in all of these cases. These results compared poorly with those in the patients who were managed surgically.

Operative Management

To our knowledge, there are no evidence-based guidelines for choosing the type of operative management of chronic ruptures of the Achilles tendon. Two classification systems have been proposed. With both, management is based on the length of the tendon defect, but to our knowledge the results of the implementation of these guidelines have not been assessed, not even by the authors reporting them.

In Myerson’s classification, a Type-1 defect is no more than 1 to 2 cm long. It is managed with end-to-end repair and...
a posterior compartment fasciotomy. A Type-2 defect ranges between 2 and 5 cm. It is managed with V-Y lengthening, with or without a tendon transfer. A Type-3 defect is >5 cm and is bridged with use of a tendon transfer, alone or in combination with a V-Y advancement.

In Kuwada's classification, a Type-I lesion is a partial rupture and is managed with plaster cast immobilization. A Type-II lesion is a complete rupture with a defect of up to 3 cm in length. It is managed with end-to-end repair. A Type-III lesion is a complete rupture with a defect of 3 to 6 cm after débridement of the ends of the tendon to healthy tissue. It is managed with a tendon graft, with or without augmentation with a synthetic graft. Finally, a Type-IV lesion is a complete rupture with a defect of >6 cm in length after débridement of the tendons ends to healthy tissue. A gastrocnemius recession, a free tendon graft, and/or a synthetic tendon graft are used for this type of lesion.

V-Y Tendon Alignment

This procedure was first described by Abraham and Pankovich for the treatment of chronic Achilles tendon ruptures. The aim is simply to achieve anastomosis of the tendon ends by making an inverted V-shaped incision in the proximal part of the tendon and repairing it in a Y-shaped fashion. Three of four patients in their study regained full strength of the triceps surae and were able to perform a single-leg heel-raise as well as they could on the normal side. The remaining patient had slight weakness of the triceps surae and a much decreased ability to perform the single-leg heel-raise. Follow-up in this small series ranged from nine to fifteen months.

Leitner et al. reported good results in three patients in whom a tendon defect of 9 to 10 cm had been managed with this technique. Kissel et al. used this technique, with augmentation of the plantaris tendon and a pullout suture, successfully in fourteen patients. Parker and Repinecz described a similar procedure (a modified Strayer gastrocnemius recession) whereby a tongue-in-groove advancement of the gastrocnemius aponeurosis was used to close a 6.5-cm defect in one patient. They reported this to be technically easier than a V-Y advancement and claimed that 50% more length could be achieved.

None of these studies were well designed or well conducted, and none involved a sufficiently large number of patients to allow us to draw useful conclusions.

Turndown Flaps

Christensen described a technique that he used for both chronic and acute tendon ruptures. A distally based 2 by 10-cm flap was fashioned in the proximal part of the tendon and turned down to cover the defect. The defect produced by the flap was also closed. Twenty-nine of thirty-nine patients in that series were reported as having a satisfactory outcome.

Silfverskiöld described a similar procedure, but he rotated the flap 180° so that the smooth tendon surface stayed superficial. Modifying this further, Arner et al. used two flaps, one medial and the other lateral, and rotated both, in opposite directions.

Gerdes et al. showed, in a cadaver study, that flap-augmented repairs had a 41% higher tensile strength than end-to-end repairs alone (217.5 ± 44.7 N compared with 153.9 ± 30.2 N).

Rush used the aponeurosis of the gastrocnemius-soleus muscle complex fashioned into a tube to reconstruct an Achilles tendon with a neglected rupture. Five patients had a good result with this technique. Bosworth showed, in a group of seven patients, that a strip of the superficial part of the proximal Achilles tendon stump can be used to augment the repair. A strip of proximal tendon on a distal pedicle is threaded through the trimmed ends of the ruptured tendon and sutured to them. No complications were reported after an average duration of follow-up of ten years.

V-Y and turndown flaps have been combined, with good results. In a series of six patients who underwent postoperative isokinetic strength testing, deficiencies in peak torque plantar flexion were found to range from 2.5% to 22% compared with values for the unaffected limb.

Mulier et al. reported on nineteen patients with a chronic Achilles tendon rupture involving a defect of >2 cm. Ten patients were treated with a gastrocnemius turndown flap (group 1), and nine patients were managed with a combination of a flexor hallucis longus transfer and a gastrocnemius turndown flap (group 2). At eighteen months, the outcomes were better in group 2. Subjective assessment showed that 40% of the patients in group 1 and 33% of those in group 2 had a decline in daily and sports activities. Objective assessment with isokinetic dynamometry at twelve months postoperatively demonstrated a 23% deficit in power and strength in group 1 compared with a 14% deficit in group 2. The range of ankle motion (compared with that on the contralateral side) was 70% in group 1 and 76% in group 2. The overall complication rate was high in this study, with seven of nineteen patients experiencing problems.

Peroneus Brevis

The peroneus brevis tendon was popularized by Pérez Teuffer. He harvested this tendon from its attachment at the base of the fifth metatarsal and passed it through a transosseous drill hole in the calcaneus. The tendon was then passed back on itself and sutured over the Achilles tendon. This procedure was used in thirty patients, all of whom had an acute tendon rupture, and twenty-eight of them were able to return to their original level of sports activity. This procedure has subsequently been used for chronic tears.

Turco and Spinella augmented an end-to-end repair of the Achilles tendon with a modification of Pérez Teuffer’s technique, by passing the tendon of the peroneus brevis through the distal stump rather than through the calcaneus. Excellent results were reported, but the outcome measures were not identified. Miskulin et al. also passed peroneus brevis through the distal Achilles tendon stump and used plantaris tendon as suture material. In their series of five patients, all patients had an improvement in peak plantar flexion torque (range, 21% to 410%) and no complications were reported at one year after the operation.
McClelland and Maffulli\textsuperscript{15} approached the Achilles tendon medially, and pulled the stump of the peroneus brevis through the inferior peroneal retinaculum, hence retaining its blood supply from the intermuscular septum. The tendon of the peroneus brevis was then woven through small coronal incisions in the distal stump of the Achilles tendon and again through similar incisions in the proximal stump. If the plantaris muscle was present, its tendon was used to augment the repair. Some investigators reported concerns that this technique could result in eversion weakness of the ankle\textsuperscript{13,27,52}. However, the peroneus longus muscle has more than twice the eversion strength of the peroneus brevis. Theoretically, if the tendon of the peroneus brevis is placed distally in a lateral-to-medial direction, it does not duplicate the medial pull of an intact Achilles tendon\textsuperscript{27}. However, the practical implications of these mechanical studies are unclear, and reconstruction with use of the tendon of the peroneus brevis has been reported to be functionally successful.

Pintore et al.\textsuperscript{53} compared the results of treatment of acute ruptures with direct end-to-end anastomosis with the results of treatment of chronic ruptures with peroneus brevis transfer. At the time of follow-up, at a mean of fifty-three months, they found the patients who had had a chronic rupture to be satisfied with the result of the procedure despite experiencing a higher postoperative complication rate and greater loss of strength and calf circumference compared with their counterparts who had had an acute rupture.

**Flexor Digitorum Longus**

Mann et al.\textsuperscript{27} used the flexor digitorum longus tendon as a graft in a series of seven patients. A medial hockey-stick-shaped incision was used to approach the Achilles tendon, and another incision was used to identify the flexor digitorum longus tendon extending from the navicular to the first metatarso-phalangeal joint. The flexor digitorum longus tendon was then transected before it divided into its separate digital branches, and its distal stump was sutured to the adjacent flexor hallucis longus tendon. The distal end of the flexor digitorum longus tendon was then delivered through the proximal wound over the Achilles tendon. The free end of the flexor digitorum longus tendon was next passed through the distal end of the Achilles tendon with use of small coronal incisions and again routed proximally and passed through similar incisions in the proximal end of the Achilles tendon. A proximal fascial turn-down flap was used to augment the repair in all patients. Six of the seven patients had a good or excellent result, with no re-ruptures and no functional disability from loss of the flexor digitorum longus tendon. The average duration of follow-up in this series was thirty-nine months.

**Flexor Hallucis Longus**

The flexor hallucis longus muscle has a long (10 to 12-cm) tendon that can be used to bridge a large Achilles tendon defect. When transferred, it also maintains the normal muscle balance of the ankle—i.e., a plantar flexor is transferred to a plantar flexor. However, athletic patients have reported that the loss of push-off strength from the hallux causes difficulty during sprinting\textsuperscript{51}. Wapner et al.\textsuperscript{52} used the flexor hallucis longus tendon as a graft in seven patients who were then followed for an average of seventeen months. Once the tendon was harvested, the surgeons passed it through a drill hole in the calcaneus and wove it through the ruptured ends of the Achilles tendon. The distal end of the flexor hallucis longus tendon was tenodesed to the tendon of the flexor digitorum longus to the second toe. As determined from a subjective questionnaire, three patients had an excellent result, three had a good result, and one had a fair result. All patients had a functionally unimportant loss of the ranges of motion of both
the ankle and the hallux. Isokinetic testing revealed a 29.5% reduction in plantar flexion power compared with the value on the normal side. No functional disability was measured secondary to harvesting of flexor hallucis longus. This observation is similar to that reported in 1977, when Frenette and Jackson found no functional loss in ten young athletes with lacerations of the flexor hallucis longus tendon, four of which were not repaired.

Advantages of flexor hallucis longus transfer include the tendon being long and durable and the muscle is stronger than that of other transfer candidates, the axis of flexor hallucis longus contraction most closely resembles that of the Achilles tendon, and contraction of the flexor hallucis longus occurs in phase with the gastrocnemius-soleus complex. Its anatomical proximity makes the operative technique easier, without the need to open other compartments, and the muscle belly aids in the provision of a vascular supply to the distal stump of the Achilles tendon.

**Gracilis**

Maffulli and Leadbetter reported harvesting gracilis tendon to reconstruct chronically ruptured Achilles tendons. If, de-
spite maximal ankle plantar flexion and traction on the ruptured stumps, the gap between the two ends of the Achilles tendon was seen to be >6 cm, the investigators harvested the gracilis tendon and used it in the reconstruction. An incision over the pes anserinus was used, and the tendon was harvested with a tendon stripper (Fig. 4). If plantaris tendon was present, it could be used to augment the repair. Of twenty-one patients followed for a mean of twenty-eight months after this procedure, two had an excellent result, fifteen had a good result, and four had a fair result.

**Fascia Lata**

Use of fascia lata to repair and augment a ruptured Achilles tendon has produced good results. Bugg and Boyd reported the outcomes of repairs of twenty-one ruptures or lacerations, ten of which were chronic. They bridged the gap in the Achilles tendon with three strips of fascia lata and with a sheet of fascia lata sutured around these grafts in a tube-like fashion, with the serosal surface facing outward and the seam placed anteriorly and sutured to the proximal and distal stumps. A wire pullout suture was also used. No formal results...
were reported, but two case reports stated that the technique provided satisfactory function and cosmetic results at twelve months postoperatively.

**Allografts**

Nellas et al. reported using two strips of freeze-dried Achilles tendon allograft in a single patient to reconstruct a 4.5-cm tendon defect following debridement of an infected wound after a primary repair. At the time of follow-up at thirty months, the patient had a good functional result but persistent weakness compared with the strength on the uninjured side.

More recently, Haraguchi et al. used Achilles tendon allografts to reconstruct both chronically ruptured Achilles tendons with a defect of >5 cm and Achilles tendons with extensive tendinopathy. In this procedure, cortical bone is removed from the patient’s heel to allow room for the allograft, which is secured in position with two 4.0-mm screws. The graft is then placed under tension and repaired to the native Achilles tendon. No formal results were reported and the duration of follow-up was not mentioned, but neither rejection of the allograft nor transmission of disease to the host was observed.

**Synthetic Grafts**

Use of synthetic materials avoids complications with donor site morbidity but increases the theoretical risk of infection. Howard et al. used a carbon-fiber synthetic graft to repair five neglected ruptures. After four to nineteen months of follow-up, the average plantar flexion strength was 88% compared with that of the contralateral ankle (40.8 kg compared with 45.46 kg). All patients had an excellent result.

Parsons et al. used an absorbable carbon-fiber composite polymer in a series of forty-eight patients with a total of fifty-two Achilles tendon ruptures, twenty-seven of which were chronic. The polymer ribbon was woven through both the proximal and the distal stump of the tendon with six, seven, or eight passes to bridge the defect. A proximal tendon flap was used at the surgeon’s discretion. According to the authors’ own unvalidated scoring system, forty-five (87%) of fifty-two reconstructions yielded a good or excellent result at a minimum of one year. It was not stated how many ruptures were acute and how many were chronic. Complications included two reruptures, two deep infections, and three superficial infections. An investigation of the use of carbon fiber in sheep tendons showed carbon fiber fragmentation to be associated with poor collagen production. With implantation of polyester fibers, the neotendon was more dense, had more collagen, and was more closely adherent.

Ozaki et al. used three layers of polypropylene mesh to treat neglected ruptures with gaps ranging between 5 and 12 cm in six patients. At the time of follow-up, at a minimum of 2.4 years, all patients showed satisfactory function and plantar flexion strength averaged 94% of that on the uninjured side. No complications were noted in the series.

Dacron vascular grafts have been employed to augment repairs of Achilles tendon ruptures and have yielded good or excellent results when used for acute ruptures. Jennings and Sefton used polyester tape with a Bunnell-type suture in the treatment of sixteen chronic ruptures. The tape was tensioned so that the ankle could just dorsiflex to neutral. One patient required removal of the tape, one had a sural nerve injury, and three had superficial wound infection. No reruptures occurred during the mean follow-up period of three years.

**Interposed Scar Tissue**

Yasuda et al. noted that the thick fibrous scar tissue found between the two ends of a ruptured Achilles tendon was strong enough to resist substantial tensile forces. They also hypothesized, on the basis of animal and clinical studies, that the interposed scar tissue would be able to form tendon-like repair tissue. All of their patients underwent magnetic resonance imaging preoperatively. The investigators only studied patients who were seen to have a thickened tendon, with diffuse high-intensity signal changes throughout, on T2-weighted images. This is thought to indicate active scar formation and healing with dense collagen fibers and proliferating fibroblasts and vessels. Six patients were included in the series. The investigators resected the middle third of the interposed scar tissue and anastomosed the two free ends with Krackow-style sutures running at least 2 cm into the native tendon. Histological examination of the resected tissue showed dense collagen fibers with blood vessels and no degenerative changes. In two specimens, these fibers were found to run parallel to the long axis of the tendon with rows of fibroblasts lying in between. In the remaining four specimens, the dense collagen fibers were not oriented along the axis of the tendon but contained highly cellular fibrovascular tissue. After surgery, no patient had difficulty walking or stair-climbing, and all were able to perform a single-limb toe rise. The mean American Orthopaedic Foot and Ankle Society ankle-hindfoot scores were 88.2 points preoperatively and 98.3 points at an average of thirty-one months postoperatively, and the difference was significant (p = 0.05).

**Chronic Achilles Tendon Tears That Have Healed in Continuity**

In some patients, the Achilles tendon tear may have healed and the tendon presents no gap on inspection and palpation. However, the patient has lengthening of the gastrocnemiussoleus-Achilles tendon complex, the Matles test is positive, the calf squeeze test findings are dubious, and there is a marked decrease in push-off ability. In these instances, the tendon may appear intact at surgery but, on opening of the paratendon, there is evidence of scarring over a long segment. In such patients, we perform a z-shortening procedure (Figs. 5-A through 5-D), making sure that the shortening produces greater equinus than is present on the contralateral side.

**Minimally Invasive and Endoscopic Management**

In patients with a chronic rupture, the skin over the gap retracts over several weeks and remains retracted until the time of the operation. During surgery, this skin is incised and is then...
stretched in a relatively acute fashion to make space for the reconstructed tendon. Therefore, following the reconstruction, the skin over the gap may well be stretched so much that its vascular supply is impaired. Reconstruction techniques involve use of relatively long incisions and are prone to be complicated by wound breakdown. Some authors have incorporated skin-flap techniques to facilitate closure following reconstructive procedures for the Achilles tendon.

To avoid this problem in patients with a chronic rupture in whom a gap is palpable, we do not expose the tendon gap. Instead, we make a 5-cm longitudinal incision 2 cm proximal and just medial to the palpable end of the proximal stump. The second incision is 3 cm long and is also longitudinal but is 2 cm distal and lateral to the distal end of the tendon rupture. Care is taken to prevent damage to the sural nerve by making this incision as close as possible to the anterior aspect of the lateral border of the Achilles tendon. The distal stump of the Achilles tendon is then mobilized, freeing it of all of the peritendinous adhesions, particularly on the lateral side. This allows access to the lateral base of the distal tendon stump close to its insertion. The ruptured tendon end is then resected back to healthy tendon, and a number-1 Vicryl locking suture (polyglactin; Ethicon, Edinburgh, United Kingdom) is run along the free tendon edge to prevent separation of the bundles. The proximal tendon stump is then mobilized from the proximal wound, and adhesions are divided. Further soft-tissue release anterior to the gastrocnemius-soleus muscle allows maximal excursion, minimizing the gap between the two tendon stumps. A Vicryl locking suture is run along the free edge of the tendon to allow adequate exposure and to prevent separation of the bundles. To bridge the gap, we use the tendon of the peroneus brevis, which we harvest in a standard fashion.

The two incisions over the Achilles tendon. The distal stump has been prepared, and the proximal stump has been delivered through the proximal wound and its end has been freshened. The tendon of the peroneus brevis has been identified at the base of the fifth metatarsal and is being harvested. The tendon of the peroneus brevis and its muscle belly have been delivered through the proximal wound and is ready for the transfer procedure.
TABLE I Recommendations for the Treatment of Chronic Ruptures of the Achilles Tendon

<table>
<thead>
<tr>
<th>Grade of Recommendation</th>
<th>Recommendations</th>
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<tr>
<td>C</td>
<td>We advocate a low threshold for tendon transfer in the operative management of chronic Achilles tendon rupture</td>
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<tr>
<td>C</td>
<td>If an end-to-end repair is not possible, our procedure of choice is transfer of the tendon of the peroneus brevis. If the gap is too large to be bridged by the peroneus brevis tendon, the tendon of the flexor digitorum longus can be harvested and used to bridge the gap</td>
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<tr>
<td>C</td>
<td>We recommend avoiding synthetic grafts because high complication rates have been described</td>
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<tr>
<td>C</td>
<td>We recommend using gracilis or semitendinosus grafts for defects of &gt;6.5 cm if local viable tendons are insufficient</td>
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longitudinal tenotomy parallel to the tendon fibers is made through both stumps of the tendon. An artery clip is used to develop the plane, from lateral to medial, in the distal Achilles tendon stump, and the peroneus brevis graft is passed through the tenotomy site. With the ankle in plantar flexion, a number-1 Vicryl suture is used to suture the peroneus brevis to both sides of the distal stump. The tendon of the peroneus brevis is then passed beneath the intact skin bridge into the proximal incision and is passed from medial to lateral through a transverse tenotomy in the proximal stump and is further secured with a number-1 Vicryl suture. Finally, the tendon of the peroneus brevis is sutured back onto itself on the lateral side of the proximal incision (Figs. 6-A, 6-B, and 6-C).

Recently, Lui described a technique for endoscopic assisted transfer of the tendon of the flexor hallucis longus to minimize soft-tissue dissection in the treatment of chronic Achilles tendon tears. The procedure is performed with use of very small incisions (<1.5 cm each), but it is unclear whether the continuity of the Achilles tendon is adequately restored and functional recovery would have to rely solely on the flexor hallucis longus. Nevertheless, the technique is minimally invasive and minimizes injury to the soft tissues. Three cases of chronic Achilles rupture were described. At a mean of fifteen months postoperatively, none of the patients walked with a limp.

Postoperative Management

We are not aware of any studies focusing specifically on postoperative management following operative treatment of chronic Achilles tendon ruptures. However, the present trend is for early mobilization after the operative repair of acute ruptures. Recent meta-analyses have shown that early functional treatment protocols, when compared with postoperative immobilization, led to more excellent subjective responses and no difference in the rerupture rate. We use the same protocol for chronic ruptures: the patient wears a below-the-knee cast for two weeks and is encouraged to bear as much weight as possible on the operatively treated limb as soon as possible. At two weeks, the cast is removed and a lower leg anterior splint is applied, allowing the ankle to be plantar flexed fully but not dorsiflexed and allowing inversion and eversion. These exercises are performed against manual resistance. At six weeks, the anterior splint is removed, and the patient gradually returns to his or her normal activities. Recovery can take as long as nine to twelve months.

The Future

Tissue engineering may prove useful for managing tendon ruptures in the future. In one study, 1-cm-long rabbit Achilles tendon defects were core bridged with a polydioxanone suture and then encapsulated in human amnion extracellular matrix seeded with third-passage fetal skin fibroblasts. There were two control groups. In control group I, defective tendons were core bridged with a polydioxanone suture and encapsulated with human amnion extracellular matrix without fibroblasts. In control group II, the defects were only core bridged with polydioxanone suture. Gross examination, light microscopy, immunohistochemical examination, scanning electron microscopy, and biomechanical measurement of the repaired tendons were performed at one, two, and three months postoperatively.

The optimal cell concentration for seeding fibroblasts was $3.5 \times 10^6$ cells/mL. Cells grew well on the extracellular matrix. Immunohistochemistry showed that the labeled seed fibroblasts played an important role in tendonization. The rate and quality of healing in the experimental group were superior to those in both control groups. The values for the structural and material properties of the implants that had received human amnion extracellular matrix seeded with third-passage fetal skin fibroblasts typically were approximately twice those of the controls, and the repaired tendons were larger in cross section and better organized histologically than the repairs performed with suture alone. The tensile strength in the experimental group was the greatest, at 81.8% of normal after three months. The authors concluded that human amnion extracellular matrix seeded with third-passage fetal skin fibroblasts promotes rapid repair of a tendon defect.

In another study, polyglycolic acid scaffolds seeded with tenocytes were implanted into hen flexor tendon defects. Twelve weeks after the operation, the tenocytes and collagen fibers became longitudinally aligned. At fourteen weeks, the tissue-engineered tendons displayed a typical tendon structure with a breaking strength of 83% of normal.

A potential application of mesenchymal stem cells is ex vivo, de novo tissue engineering. This technique involves construction of whole body tissues in the laboratory and their subsequent implantation into patients. Such tissue-engineered tendons potentially could be used to bridge large areas of tissue loss.

Tissue engineering is an emerging field, and many difficulties need to be overcome before this approach becomes a
real option in the management of tendon disorders. For example, effective vascularization and innervation of implanted tissue-engineered constructs must take place. Vascularization is important for the viability of the construct. Innervation is required for proprioception and to maintain reflexes that are mediated by Golgi tendon organs to protect tendons from excessive forces.

**Overview**

Chronic Achilles tendon ruptures are uncommon but potentially debilitating. The choice of management is partly guided by the type of tendon lesion, with most injuries requiring operative management. Many techniques can be used to repair or reconstruct a tendon with a chronic rupture. It is difficult to compare different techniques. Most studies have been retrospective and small and have focused on the results of a single technique (Table I). Functional outcome measures have also been diverse, given the highly variable outcome criteria that have been applied. Tissue engineering shows promise, but additional research and clinical trials are needed to evaluate its efficacy in humans.

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Nicola Maffulli, MD, MS, PhD, FRCSc(Orth)
Department of Trauma and Orthopaedic Surgery, Keele University School of Medicine, Thornburrow Drive, Hartshill, Stoke on Trent ST4 7QB Staffs, England.
E-mail address: n.maffulli@keele.ac.uk

Adam Ajis, MRCSed
Department of Trauma and Orthopaedic Surgery, Macclesfield District General Hospital, Victoria Road, Macclesfield SK10 3BL, England

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